

The hunt for old novae

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Abstract. We inform on the progress of our on-going project to identify and classify old classical novae, using deep *UBVR* photometry and subsequent spectroscopy for a proper candidate confirmation, and time-resolved observations in order to find the orbital period and other physical properties of the identified old novae. This way, we have already increased the number of confirmed southern and equatorial post-novae from 33 to 50, and determined new orbital periods of eight objects. As an example, we summarise the results on V728 Sco (Nova Sco 1862) which we found to be an eclipsing system with a 3.32 h orbital period, displaying high and low states similar to dwarf-nova outbursts. Analysis of the low-state eclipse indicates the presence of a small hot inner disc around the white dwarf component.

1. Tracking down the CV within the nova

1.1. The species

It is undisputed that a nova eruption represents an event in a cataclysmic variable (CV). The old nova DQ Her (Nova Her 1934) has become known as the prototype intermediate polar (Warner 1983), RR Pic (Nova Pic 1925) shows all the properties of an SW Sex star (Schmidtbreick et al. 2003), and there is compelling evidence for ancient nova shells around the dwarf novae Z Cam and AT Cnc (Shara et al. 2007, 2012). In principle, every CV should experience nova eruptions, as long as its mass-transfer rate is sufficiently high to accumulate the necessary mass on the white dwarf during its lifetime.

Still, there are several unresolved questions concerning the relation between novae and CVs. Which CV parameters are favourable for the system to undergo a nova eruption? The mass-transfer rate is easily identified as an important one, but what about, e.g., the strength of the magnetic field of the white dwarf? Another point concerns the long-term consequences of the nova eruption. Do the white dwarfs gain or lose mass in the long run? And how does the eruption affect the mass-transfer rate, i.e. do post-novae go into hibernation (Shara et al. 1986; Pralnik & Shara 1986)?

One way to find an answer is to study the post-novae as a group and to compare with the general CV population. However, this needs samples of a statistically significant size to distinguish the rule from the exception, and the novae are severely lacking

in this respect. In the following we restrict our research to novae that have erupted before 1980, in order to allow ~ 30 yr for the contribution of the ejected material to become negligible (at least in the optical range), so that the properties of the underlying CV can be studied. The catalogue of CVs by Downes et al. (2005) lists 200 such systems, but only 28 of these have good orbital periods¹, and about 3/4 of the reported novae still lack spectroscopic confirmation or even the identification of a candidate for the post-nova.

1.2. Picking up the scent

In order to improve this situation we have started a program to identify nova candidates, to confirm them spectroscopically and to determine their orbital period. First results and a detailed description can be found in Tappert et al. (2012). For the identification of nova candidates we take advantage of CVs being three-component systems (white dwarf, late-type star, accretion disc or stream), placing them apart from the main-sequence in a colour-colour diagram. We therefore use *UBVR* photometry to select the candidates, low-resolution spectroscopy to examine them for the presence of typical emission lines, and time-series spectroscopy and/or photometry to measure the orbital period. As an example for a system that went through all our different bins (unidentified candidates – unconfirmed candidates – confirmed post-novae without orbital period – systems with an established orbital period) we present the data on V728 Sco in Fig. 1. We will come back to that object in Section 2.

1.3. Game count then and now

At the start of our program in 2009, the 153 reported pre-1980 novae on the southern hemisphere ($\delta \leq +20^\circ$) included 120 unconfirmed objects, 86 of them without a proper candidate. For 24 post-novae a value for the orbital period was listed. Almost four years and several observing runs (not much favoured by meteorological conditions) later, we have increased the number of confirmed post-novae to 50 (from 33) and determined the orbital period for eight objects. One reported nova, V734 Sco, turned out to be a Mira variable whose photometric variation was mistaken for a nova eruption². This still leaves about 2/3 of the sample of pre-1980 novae as unconfirmed objects, and further observations are in preparation to significantly decrease that number.

2. V728 Sco: a rare animal?

The system V728 Sco corresponds to a nova eruption from 1862 (Tebbutt 1878). This makes it the third oldest confirmed post-nova (not counting the likes of Z Cam and AT Cnc) and thus an interesting object to examine the consequences of the nova eruption on the underlying CV. A detailed study can be found in Tappert et al. (2013). Here we present a summary of the main results.

Most known post-novae are high mass-transfer systems, with their spectra being characterised by a steep blue continuum and weak emission lines (e.g., Ringwald et al.

¹This includes the period of CP Pup, which is one of the few below the period gap, and whose orbital nature is now reported to be doubtful; see the contribution by Mason et al. in these proceedings.

²In Tappert et al. (2012) we had reported the same conclusion for V1310 Sgr, but that candidate is probably not identical to the reported nova (Schaefer, private communication).

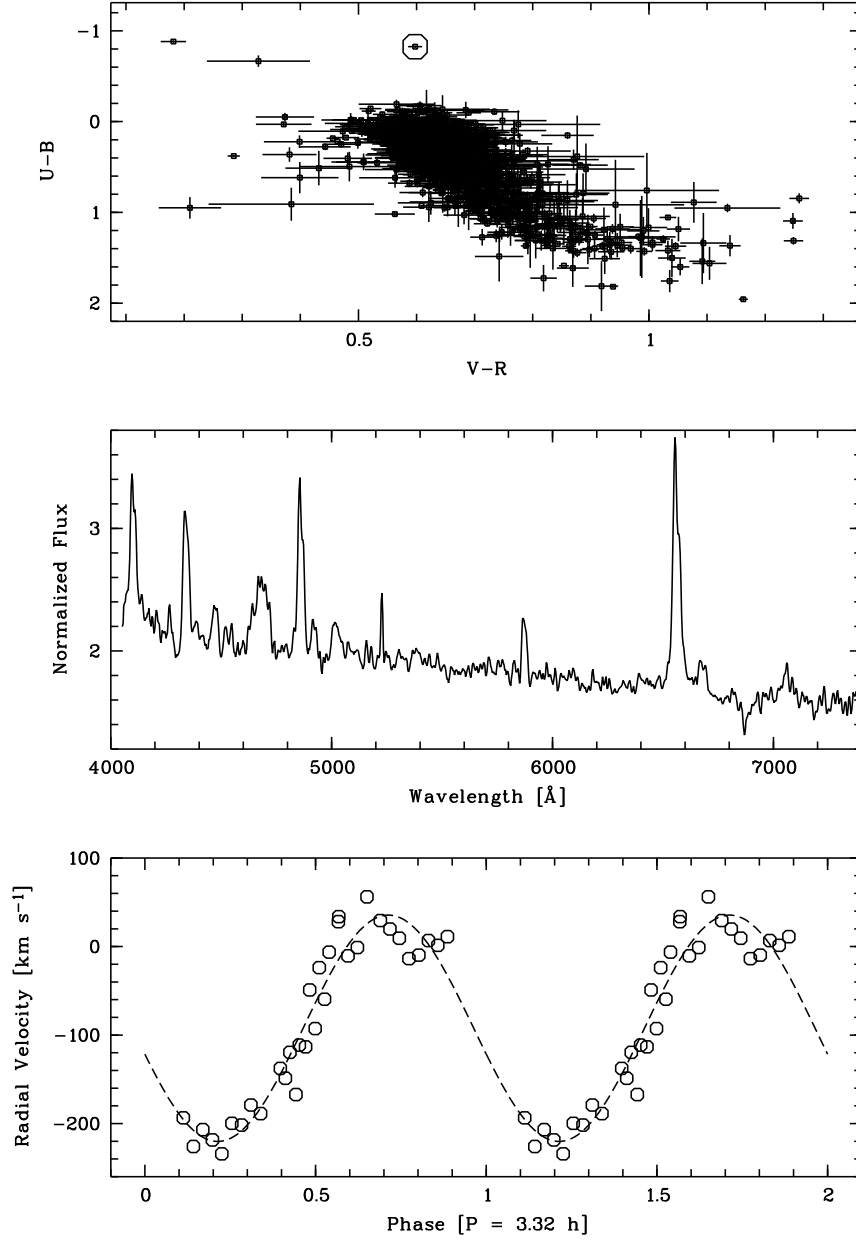


Figure 1. The old nova V728 Sco as an example. *Top:* *UBVR* photometry of a $4.5' \times 4.5'$ field centred on the reported coordinates. The nova (marked by a circle) turned out to be $\sim 2'$ NW of that position. *Middle:* Low-resolution spectroscopy of the identified candidate. The spectrum shows prominent Balmer, H ϵ and H γ emission lines. *Bottom:* Radial velocities of the H α emission line folded on the orbital period ($P_{\text{orb}} = 3.32 \text{ h}$). The dashed curve represents the best sine fit to the data.

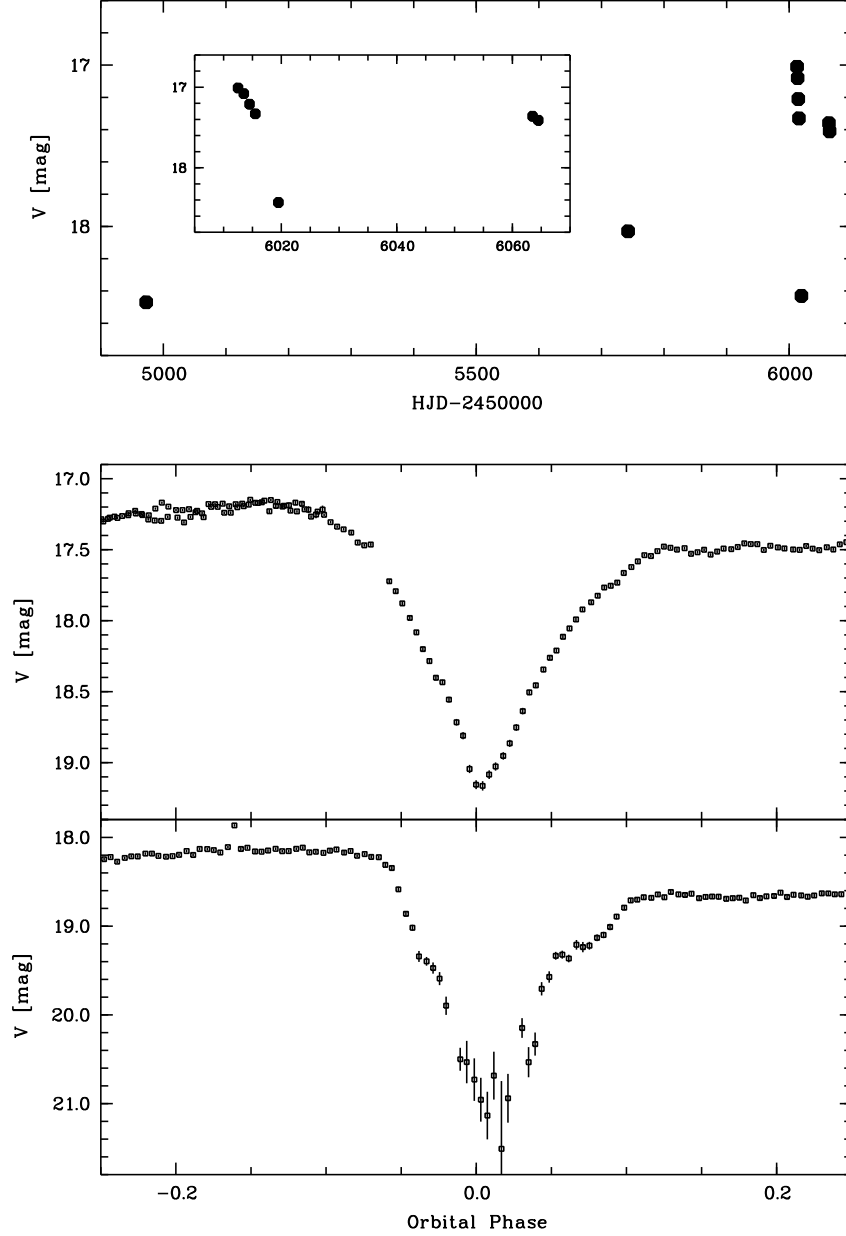


Figure 2. Time-series photometric data on V728 Sco. *Top:* Long-term light curve (out-of-eclipse data) from 2009 May 20 to 2012 May 16. The inset presents a close-up of the 2012 March to May data. *Middle:* High-state eclipse from 2012 March 28. *Bottom:* Low-state eclipse from 2012 April 1. Note the different y-scale in the eclipse data.

1996). The spectrum of V728 Sco, however, is more reminiscent of that of a dwarf nova: a moderately blue continuum and strong emission lines of the Balmer and HeI series (middle plot in Fig. 1). Such properties let suspect a comparatively low mass-transfer rate. The only feature that appears out of place for a dwarf nova is the strong Bowen/HeII blend at $\lambda 4641\text{--}4686\text{ \AA}$, which indicates the presence of a hot component somewhere in the system. The detection of long-term variations that resemble dwarf-nova outbursts (top plot in Fig. 2) represents further evidence for a comparatively low mass-transfer rate.

Time-series data show the object to be eclipsing with an orbital period $P_{\text{orb}} = 3.32\text{ h}$. This places V728 Sco within the regime of the SW Sex stars, high mass-transfer systems that dominate the orbital period range 2.8–4 h (Rodríguez-Gil et al. 2007a,b, Schmidtobreick et al., these proceedings). Thus the more puzzling is the low mass-transfer behaviour of V728 Sco.

In high state, the triangular shape of the eclipse indeed is very similar to that of SW Sex stars (e.g., Stanishev et al. 2004). However, in low state the eclipse is much more revealing, showing the ingress and egress of the hot spot and of the central object (Fig. 2). While the latter usually is expected to be the white dwarf, our analysis of the ingress and egress times yields a radius for that central component of $R \sim 0.09 R_{\odot}$, significantly larger than a white dwarf. We conclude that this component represents a hot and optically thick inner disc, that is caused by irradiation from the still eruption-heated white dwarf. The presence of such disc would also explain the small-amplitude and high-frequency nature of the outbursts (Schreiber et al. 2000).

While most old novae indeed seem to be high mass-transfer systems (Iben et al. 1992), there are some known exceptions, e.g. the old novae XX Tau (Schmidtobreick et al. 2005) and V446 Her (Honeycutt et al. 1995). Due to its eclipsing nature V728 Sco certainly appears as the member of this group that is the most interesting for further studies. It is most desirable to monitor the long-term behaviour more extensively to examine the frequency and the stability of the outbursts. Schreiber et al. (2000) predict increasing amplitude and decreasing frequency over time, as the white dwarf continues to cool down. Additionally, high S/N and high time-resolved data (especially in low state) should be able to determine accurate physical system parameters of V728 Sco.

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